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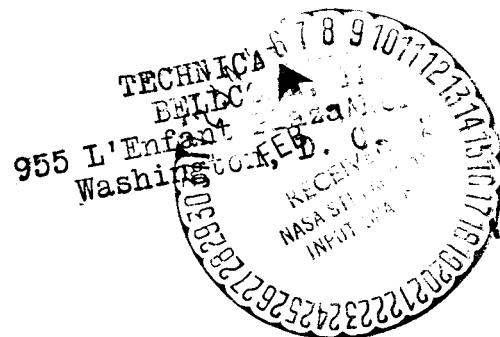
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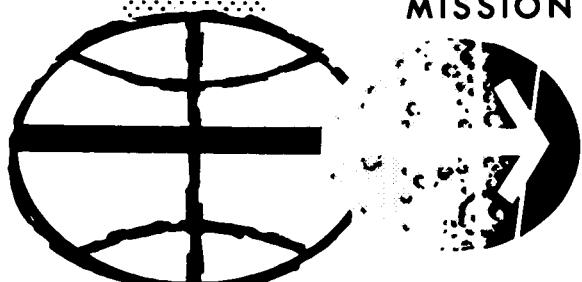
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APOLLO 7
DISPERSION ANALYSIS



Guidance and Performance Branch

MISSION PLANNING AND ANALYSIS DIVISION



MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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PROJECT APOLLO

APOLLO 7 DISPERSION ANALYSIS

By Melvin R. Rother, Aldo J. Bordano, and Joe W. Nolley
Guidance and Performance Branch

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MISSION PLANNING AND ANALYSIS DIVISION
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CONTENTS

Section	Page
1.0 SUMMARY	1
2.0 INTRODUCTION	2
3.0 ANALYSIS AND RESULTS	2
3.1 Rendezvous Dispersions	2
3.2 Individual SPS Maneuver Dispersions . . .	5
3.3 Propellant Dispersions	6
3.4 Unit GNCS Dispersions	6
3.5 Reentry Dispersions	7
4.0 CONCLUSIONS	8
5.0 REFERENCES	30

TABLES

Table		Page
I	APOLLO 7 MISSION SEQUENCE OF EVENTS	9
II	SUMMARY OF PERFORMANCE PARAMETERS DURING RENDEZVOUS	10
III	SUMMARY OF TRAJECTORY PARAMETERS DURING RENDEZVOUS	12
IV	SPS-1 INDIVIDUAL MANEUVER ANALYSIS	17
V	SPS-2 INDIVIDUAL MANEUVER ANALYSIS	18
VI	SPS-3 INDIVIDUAL MANEUVER ANALYSIS	19
VII	SPS-4 INDIVIDUAL MANEUVER ANALYSIS	20
VIII	SPS-5 INDIVIDUAL MANEUVER ANALYSIS	21
IX	SPS-6 INDIVIDUAL MANEUVER ANALYSIS	22
X	SPS-7 INDIVIDUAL MANEUVER ANALYSIS	23
XI	SPS-8 INDIVIDUAL MANEUVER ANALYSIS	24
XII	SPS PROPELLANT FOR APOLLO 7	25
XIII	UNIT G&N SYSTEM ERROR ANALYSIS SUMMARY FOR THE SPS-1 AND SPS-2 MANEUVERS	26
XIV	UNIT GNCS ERROR ANALYSIS SUMMARY FOR THE SPS-5 AND SPS-8 MANEUVERS	28

Apollo 7 Dispersion Analysis

By Melvin R. Rother, Aldo J. Bordano, and Joe W. Nolley

1.0 SUMMARY

The dispersion analysis for the Apollo 7 mission is based on the Apollo 7 spacecraft operational trajectory. The analysis is presented in the following four parts: (1) rendezvous analysis, (2) individual service propulsion system (SPS) maneuver analysis, (3) SPS propellant budget, and (4) a unit guidance, navigation, and control system (GNCS) error analysis.

The rendezvous analysis consisted of a Monte Carlo analysis based upon analytic equations that adequately model the retargeting criteria to be used during real time of the mission. The dispersions are presented for the spacecraft maneuvers required to accomplish rendezvous with the S-IVB and for the amount of propellant needed to accomplish the rendezvous.

In the Monte Carlo analysis for individual SPS maneuvers, dispersions between the SPS maneuvers were not correlated. Each maneuver was simulated as follows: Assume a tracking uncertainty on the trajectory update, use nominal targets, and assume vehicle performance, GNCS system, and pointing errors. The resulting trajectory and propellant dispersions are presented.

Next, a summary of the SPS propellant needed to perform the maneuvers described in the Apollo 7 operational trajectory is presented. This summary is derived from data presented in the rendezvous and individual SPS maneuver sections of this note and is based on the SPS engine performance characteristics presented in the CSM/LM Block II Handbook, dated April 1968. The expected mean of SPS propellant needed to perform the scheduled maneuvers is 7545 lb and the 3σ deviation is approximately 175 lb.

Finally, a "unit" GNCS error analysis is presented. The study consisted of modeling the nominal SPS maneuvers and then, using a standard error model, simulating cases using the GNCS errors specified in the Guidance System Operations Plan. Results are presented as actual velocity achieved in UVW components. No attempt is made to convert this data to resulting trajectory parameters, but it can be converted by

individuals interested in the effects of GNCS errors on specific orbital parameters.

These analyses show that, allowing for 3σ dispersions, the Apollo 7 mission as presented in the operational trajectory can be accomplished.

2.0 INTRODUCTION

The dispersion analysis presented is for the Apollo 7 operational trajectory (refs. 1 and 2). Revisions to the operational trajectory will be considered in later dispersion studies.

Apollo 7 is an open-ended, near-earth-orbital mission of up to 11 days duration and includes eight SPS maneuvers. An outline of the mission sequence of events is given in table I. The first two SPS burns (NCC and NSR) are in the rendezvous sequence and are targeted to set up a desired relative state between the spacecraft and the S-IVB. The maneuvers are controlled by the GNCS using external ΔV guidance.

The third SPS burn is controlled by the stabilization and control system (SCS) and is targeted to establish a sufficient orbital lifetime to complete the nominal mission and provide reaction control system (RCS) deorbit capability. Furthermore, the maneuver is targeted to set up a fixed propellant level at the beginning of the fifth SPS burn by having the total burn time for the first three SPS maneuvers be 31.1 seconds. The SPS-4 and SPS-6 maneuvers are minimum impulse burns performed under the GNCS external ΔV mode and are in-plane, horizontal, and posigrade. There are no targeting requirements. SPS-5 is a 57-second maneuver that is initially controlled by the GNCS external ΔV mode with a manual take over at 30 seconds. The maneuver is targeted to burn for 57 seconds and to achieve a 90- by 220-n. mi. orbit.

The seventh SPS burn is controlled by the SCS and is targeted to maintain the 90- by 220-n. mi. orbit and to locate perigee so that a landing in the primary recovery area is possible. The last SPS maneuver (SPS-8) is the deorbit maneuver and is controlled by the GNCS external ΔV mode.

3.0 ANALYSIS AND RESULTS

3.1 Rendezvous Dispersions

The main objective of the rendezvous analysis was to determine if dispersed conditions would reveal any problems areas in performing the

sequence of maneuvers during the first 30 hours of the mission. Especially important was the SPS propellant consumed during rendezvous since the total burn time of the first three scheduled SPS burns could not exceed 31.1 seconds.

This portion of the analysis was generated with a Monte Carlo simulation developed by TRW under MSC/TRW Task A-54.2 and detailed results may be found in reference 3. A mathematical model of the re-targeting criteria to be used during the real time of the mission was designed to simulate the trajectory-associated events included in the first 30 hours of the mission from orbital insertion to rendezvous. The events simulated during this portion of the mission were as follows:

1. Initialization at orbital insertion
2. Phasing (null) maneuver
3. Corrective combination maneuver (NCC-1)
4. Corrective maneuver (NCC-2)
5. Coelliptic maneuver burn (NSR)
6. Terminal phase initiation (TPI)
7. Midcourse correction maneuvers (MCC-1 and MCC-2)
8. Terminal phase finalization (TPF)

The simulation was initialized at orbital insertion assuming perfect knowledge of the CSM/S-IVB state vector. Therefore, the uncertainty that exists prior to the first ground update is due entirely to drag and gravitational potential errors. All state vector propagation was accomplished with an analytic ephemeris generator (AEG) having a drag and earth potential model. All vehicle maneuvers were performed impulsively with provisions to simulate prethrust vehicle misalignment and engine mistrim, IMU platform initial misalignment, static gyro drift of platform, accelerometer bias, accelerometer scale factor, accelerometer misalignment, and engine performance errors. Navigation updates of the vehicle state vector were simulated with ground and relative vehicle tracking data. After NSR, the updates were based on CSM sextant tracking (angles only) of the S-IVB. State vector uncertainties were formed from tracking normal matrices, supplied by MSC/TRW Task A-153, which reflect instrumentation bias, systematic errors, and measurement noises.

The NCC-1 and NSR maneuvers were always simulated using the SPS engine. A trim maneuver was not performed after NCC-1 to allow the NCC-2

maneuver to be made with the SPS engine if at all possible. A trim maneuver was always made with the RCS engines following the NSR burn. The NCC-2 burn was executed using the SPS engine if the required ΔV is greater than 15 fps and with the RCS engines if the required ΔV is less than 15 fps. All other maneuvers for this portion of the mission were performed with the RCS engines.

The TPI maneuver was performed when the angle between the line of sight to the S-IVB and the local horizontal reached 27.45° . After the last ground update, prior to NCC-2, the estimated state vector was propagated ahead (adding NSR perfectly) to solve for TPI time to test the effects of not performing the NCC-2 maneuver. The actual time of TPI was based on relative tracking after the NSR maneuver.

Midcourse correction maneuvers were made 14 and 21 minutes, respectively, after the TPI maneuver to simulate the nominal transfer time between TPI and TPF. The TPF maneuver was simulated by matching the velocity of the CSM with S-IVB at the distance of closest approach of the two vehicles. No attempt was made to simulate the braking maneuvers for TPF.

The results of the rendezvous dispersion analysis were based on a 200-cycle Monte Carlo simulation in which the initial conditions and error sources were generated randomly in each cycle. Besides the mean and standard deviation for various parameters, the smallest and largest sample encountered for each maneuver were considered to be of interest.

Table II is a summary of the performance parameter dispersions in the actual maneuvers. The UVW coordinate system referred to has the U component in the radial direction, V in the down-range direction, and W out-of-plane. The trim velocity is defined as the maneuver required to drive the postburn sensed ΔV , ΔV_s , to the preburn commanded ΔV ,

ΔV_C ; i.e.,

$$\Delta V_{\text{TRIM}} = \Delta V_C - \Delta V_S$$

Note that the NCC-2 burn was executed with the SPS engine ($\Delta V > 15$ fps) 60 times and with the RCS engine ($\Delta V < 15$ fps) 140 times. There were 37 RCS burns for the NCC-2 maneuver in the undesirable range of a ΔV of 10 to 15 fps. This range is undesirable since it requires so much RCS propellant, but is too small to be an SPS maneuver.

Table III is a summary of the actual trajectory dispersions which result from maneuver execution errors, targeting logic, and navigation

uncertainties. Altitudes are measured above the Cape radius of 20 909 900 ft. Phasing is the magnitude of the central angle separating the CSM and S-IVB; the differential altitude is the CSM radius minus the S-IVB radius; and the relative range is the magnitude of the vector difference in the positions of the two vehicles. The TPI shift is defined as the difference between the onboard or ground solution and the nominal time in the operational trajectory (negative if early). Distance of closest approach (DCA) shift is similarly defined as the variation in coast time from MCC-2 to DCA.

3.2 Individual SPS Maneuver Dispersions

After the rendezvous, the Apollo 7 mission becomes less constrained. A Monte Carlo analysis was performed for each SPS maneuver and was independent of all other maneuvers. The individual maneuver analyses can be used by the mission designers and flight controllers to analyze the capability of the spacecraft to achieve its nominal target conditions, assuming a nominal state at the update time. Each individual Monte Carlo analysis was modeled as follows: Assume the spacecraft's estimated state was the nominal value and cause the actual state to differ by an uncertainty introduced by tracking errors, perform the maneuver with the nominal targets, and randomly sample GNCS and performance errors. The above model produces meaningful results since it effectively shows how accurately the spacecraft achieves its targets. Fifty Monte Carlo cycles were made where GNCS, performance, and tracking errors were considered. All maneuvers were simulated in this manner except SPS-3 and SPS-7 which are controlled by the SCS and, therefore, considered SCS errors instead of GNCS errors. Fifty Monte Carlo runs which simulated pointing errors were also made for SPS-1, SPS-2, and SPS-8. SPS-4 and SPS-6 are minimum impulse and are not significantly affected by pointing errors. SPS-5 is 57 seconds long and is not affected significantly by pointing error. No pointing errors were simulated for burns three and seven which are SCS controlled. Reference 4 gives results of pointing errors for these maneuvers.

Tables IV through XI present the results of the individual Monte Carlo analyses for the SPS maneuvers. The tables present the nominal value, the mean, the standard deviation, and the minimum and maximum samples for seventeen trajectory parameters. Blank spaces in the standard deviation column represent 3σ dispersions that meet the following criteria:

$v, v_u, v_v, v_w \dots \dots \dots < 1 \text{ fps}$

$v_g, v_{gx}, v_{gy}, v_{gz} \dots \dots \dots < 1 \text{ fps}$

$h_a, h_p \dots \dots \dots < 0.5 \text{ n. mi.}$

$\omega, \Omega, i, \phi, \lambda \dots \dots \dots < 0.1 \text{ deg}$

Dispersions smaller than the above criteria were considered to be insignificant. V is the magnitude of the actual velocity achieved during the maneuvers, while V_u , V_v , and V_w are the components in the UVW system which is defined in section 3.1. V_g is the magnitude of the velocity residual and V_{gx} , V_{gy} , and V_{gz} are the residual components in inertial measurement unit (IMU) platform coordinates. The magnitude of the velocity residual at the end of the maneuver is always positive, and so the mean is positive and usually not near zero. On the other hand, the individual residual components are near zero since they have a direction associated with them. The tables show that the GNCS maneuvers performed without pointing errors produced negligible dispersions. SCS maneuvers produce larger dispersions, but these are also not significant. When pointing errors are considered, dispersions increase significantly. Since the mission is very flexible after the rendezvous is accomplished, the largest trajectory dispersions calculated do not cause any particular concern.

3.3 Propellant Dispersions

The propellant dispersions are based on a 50-cycle Monte Carlo simulation for each SPS burn of the Apollo 7 mission. The dispersions are based on errors in maneuver execution only and do not result from other errors such as boiloff, propellant loading, and targeting procedures. The propellant dispersions presented in this document are the results of the dispersion analysis only and should not be considered the official propellant budget for the Apollo 7 mission. The official propellant budget will be presented by the Consumable Analysis Section of MPAD. A description of the individual maneuver simulations is presented in section 3.2 of this note. The mean value and 3σ deviations were totaled to obtain reasonable propellant dispersions. Since the SPS-5 burn is scheduled to be cut off manually, a 1-second error in cutoff time was assumed which results in an additional 65 lb of propellant that could be used.

The dispersions resulting from the individual maneuver analysis approach show expected dispersions in performing the nominal maneuvers. If the maneuvers were correlated and if the rendezvous consumed 3σ or even a greater amount of propellant, the third SPS maneuver would be retargeted to consume only an amount that would cause the total to be used by the first three SPS burns to be a fixed amount. Hence, even large known dispersions in the first two SPS maneuvers can be corrected by the third SPS maneuver. Therefore, the budget obtained by treating the maneuvers independently is acceptable.

The results of the analysis of the SPS propellant dispersions are presented in table XII. These results show that the 3σ deviation will be approximately 175 lb when the maneuvers are uncorrelated. A

mathematical model of the retargeting criteria to be used during the real time of the mission was a part of the rendezvous simulation and resulted in a 3σ SPS propellant usage for those maneuvers of 227 lb. However, there is a mission constraint which states that the total burn time for the first three SPS burns cannot exceed 31.1 seconds and the SPS-3 must be at least 5 seconds in duration to achieve the control mode objective and maintain RCS deorbit capability. Thus SPS-3 could be retargeted with a smaller ΔV due to rendezvous propellant dispersions, and the total propellant dispersion would remain valid.

3.4 Unit GNCS Dispersion

An analysis was performed to study the effects of GNCS errors on the scheduled maneuvers of the Apollo 7 mission. The only SPS maneuvers analyzed are burns one, two, five, and eight since burns four and six are minimum impulse and burns three and seven utilize the SCS system. GNCS errors included in the study were accelerometer bias, scale factor, and misalignment errors, as well as gyro drift errors (ref. 5). For gyro drift cases, the platform was aligned 30 minutes prior to ullage ignition. The parametric study is not in terms of standard deviations (sigmas) of the error sources, but in terms of units normally associated with the error sources such as meru, ft/sec^2 , parts per million (PPM), and minutes of arc. The following error sources and their magnitudes were considered in this study:

Accelerometer bias errors, ft/sec^201, .1, .4
Accelerometer scale factor errors, PPM	100, 1000, 5000
Accelerometer misalignment errors, min of arc	1, 5, 15
Gyro drift errors, meru	2, 20, 100

The analysis is really a failure analysis instead of a dispersion analysis since some of the error sources are nearly 100σ values. This portion of the analysis is intended for those interested in the effects of individual hardware errors and not those interested in total trajectory dispersions.

The results of the study are presented in tables XIII and XIV as actual velocity increments from the maneuvers in components of the UVW system. The velocity dispersions can be easily converted to desired trajectory parameter dispersions by the user. This approach was taken since it would be impractical to include dispersions of all trajectory parameters that are of interest. Reference 6 which presents the effects of GNCS errors on various trajectory parameters during the Apollo 7 mission can be used in conjunction with this study to under-

stand how the velocity dispersions are converted into trajectory dispersions.

3.5 Reentry Dispersions

The Reentry Studies Section states that the touchdown dispersions incurred during reentry and resulting from CMC navigation accuracy, 3σ hardware errors, initial state vector errors of expected accuracy from MSFN tracking, environment, and CM performance characteristics are extremely small. Reference 8 has shown that the standard deviations of the down-range and cross-range dispersions are generally less than 3-n. mi. Therefore, the touchdown errors that can be expected for this mission, assuming 3σ error sources of a comparable magnitude of those of reference 8, should cause no reentry or recovery problems.

4.0 CONCLUSION

Results of the dispersion analysis do not reveal any problem areas on the Apollo 7 mission as scheduled in the operational trajectory. Revisions to the Apollo 7 operational trajectory will be considered in later dispersion studies. Areas of particular interest are as follows:

1. Allowing for 3σ SPS propellant dispersions of 227 lb during the rendezvous, SPS-3 will be at least 5 seconds in duration and, hence, meets its control mode test objective and achieves RCS deorbit capability.
2. The 3σ dispersions show that TPI will occur within ± 5 minutes of the nominal TPI time when the solution is based on relative tracking after the NSR maneuver. This time slip is allowable.
3. Since the results showed that the NCC-2 maneuver would be executed with the RCS engine 70 percent of the time (an undesirable situation) even when the NCC-1 maneuver was not trimmed, a new philosophy for performing the NCC-1 maneuver evolved. The new philosophy says that if the residual after the NCC-1 maneuver is less than 10 fps, the NCC-1 maneuver will be trimmed with the RCS and NCC-2 will not be performed. Reference 7 contains details of the new philosophy.
4. The 3σ SPS propellant dispersion, including a 1-second error in cutoff of the manual maneuver, is 175 lb.
5. The Monte Carlo analysis of the individual SPS maneuvers after the rendezvous has been accomplished shows that no problems exist in performing the maneuvers scheduled in the operational trajectory.

TABLE I.- APOLLO 7 MISSION SEQUENCE OF EVENTS

Event	Rev. no.	g.e.t., day:hr:min	Burn duration, sec	ΔV , fps	Pitch ^a , deg	Yaw ^b , deg	Purpose	Thrust vector control mode	Station in contact
Orbit insertion	1	0:00:10					Insert into 123- by 153-n. mi. orbit (above Cape Kennedy reference radius)	ETR	
S-IVB/CSM separation (RCS)	2	0:02:55	2.6	1	0	0	Separate from S-IVB	GNCS	HAW
SM RCS phasing burn	3	0:03:20	19.2	7.5	-5	180	Set up proper phase offset for rendezvous	GNCS	ANG
First SPS burn	17	1:02:24	10.1	209	-78	1.4	Corrective combination maneuver	GNCS	CRO
Second SPS burn	18	1:04:00	8.8	185.6	59	180	NSR (concentric maneuver)	GNCS	CRO
TPI (RCS)	19	1:05:23	42.2	17.1	32.77	5.03	Terminal phase initiate	GNCS	ACN
Separation after rendezvous	20	1:06:20	4.9	2	0	0	To assure no recontact problem with CSM and S-IVB	GNCS	TEX
Third SPS burn	58	3:19:43	12.2	260.8	3.5	-102.8	Position and size ellipse for CSM RCS deorbit to ETR, sets up auxiliary gauging system test	SCS	CRO
Fourth SPS burn	77	5:00:52	.5	15.0	-3	0	Minimum impulse test	GNCS	ETR
Fifth SPS burn	105	6:21:08	56.2	1277.0	16	-84	Gauging test, adjust ellipse for life time, position and size ellipse for CM RCS deorbit	GNCS/MTVC	ETR
Sixth SPS burn	134	8:19:42	.5	16.9	-2.9	-4.55	Minimum impulse test	GNCS	ETR
Seventh SPS burn	150	9:21:25	19.6	494	-48	-98	True anomaly adjust for deorbit burn	SCS	ETR
Eighth SPS burn	164	10:21:08	9.8	259	-51	180	Deorbit	GNCS	HAW

^aPitch from local horizontal.^bYaw from velocity vector.^cThe parameters for the orbit insertion burn will be presented in the launch vehicle operational trajectory to be published.

TABLE II.- SUMMARY OF PERFORMANCE PARAMETERS DURING RENDEZVOUS

Parameter	Mean	Standard deviation	Smallest sample	Largest sample
Null Magnitude of null velocity, fps	6.94	0.44	5.39	8.15
NCC-1 Magnitude of NCC-1 velocity, fps	221.53	6.45	209.17	254.00
SPS propellant used, lb	689.71	20.74	651.88	798.01
Burn duration, sec	10.86	0.33	10.19	12.48
Magnitude of trim required ^a , fps	2.05	1.16	0.19	6.36
\dot{U} component of trim, fps	0.06	0.46	-1.15	1.40
\dot{V} component of trim, fps	0.21	1.64	-4.17	5.63
\dot{W} component of trim, fps	0.09	1.62	-4.38	5.74
NCC-2 Magnitude of NCC-2 velocity ^b , fps	12.12	9.51	0.10	56.78
Accumulated propellant used	706.46	39.36	651.88	871.31
Total SPS, lb				
NSR Magnitude of NSR velocity, fps	201.43	15.00	168.79	268.79
SPS propellant used, lb	610.64	46.49	506.15	817.85
Burn duration, sec	9.62	0.73	8.04	12.79
Magnitude of trim required, fps	1.77	0.94	0.19	5.08

^aNot executed^b140 were RCS (<15 fps), mean $\Delta V = 7.04$ fps, 60 were SPS (>15 fps), mean $\Delta V = 24.0$ fps

TABLE II.- SUMMARY OF PERFORMANCE PARAMETERS DURING RENDEZVOUS - Concluded

Parameter	Mean	Standard deviation	Smallest sample	Largest sample
NSR - Continued				
\dot{U} component of trim, fps	-0.02	0.66	-1.74	2.47
\dot{V} component of trim, fps	-0.03	1.30	-4.80	3.93
\dot{W} component of trim, fps	-0.02	1.38	-4.19	3.84
TPI				
Magnitude of TPI velocity, fps	17.18	0.53	15.60	18.68
MCC1				
Magnitude of MCC1 velocity, fps	1.90	1.31	0.08	8.16
MCC2				
Magnitude of MCC2 velocity, fps	0.87	0.67	0.03	4.16
TPF				
Magnitude of TPF velocity, fps	18.14	0.97	15.50	21.00
Accumulated propellant used				
Total SPS, 1b	1317.10	75.48	1210.57	1689.16

TABLE III.— SUMMARY OF TRAJECTORY PARAMETERS DURING RENDEZVOUS

Parameter	Mean	Standard deviation	Smallest sample	Largest sample
Separation				
Longitude, deg	-163.77	.62	-165.36	-162.15
Latitude, deg	13.28	.44	12.19	14.38
Apogee altitude, n. mi.	171.57	6.39	159.88	193.48
Perigee altitude, n. mi.	120.86	3.39	113.94	126.46
Longitude of ascending node, deg	32.86	.25	32.28	33.43
Inclination, deg	31.64	.03	31.59	31.70
Argument of perigee, deg	68.41	2.81	60.61	77.63
Mean anomaly, deg	-41.89	3.09	-51.78	-32.17
NULL, CSM				
Longitude, deg	-60.81	.72	-62.78	-59.07
Latitude, deg	24.60	.34	23.78	25.45
Apogee altitude, n. mi.	166.17	6.10	153.06	185.27
Perigee altitude, n. mi.	119.69	3.60	111.79	128.36
Longitude of ascending node, deg	32.66	.25	32.08	33.24
Inclination, deg	31.62	.02	31.58	31.68
Argument of perigee, deg	75.71	3.21	66.82	85.98
Before NCC-1, CSM				
Apogee altitude, n. mi.	161.17	6.49	149.53	188.58
Perigee altitude, n. mi.	122.53	3.36	115.37	129.42
Longitude of ascending node, deg	25.59	.26	25.00	26.27
Inclination, deg	31.61	.02	31.56	31.67
Argument of perigee, deg	77.98	3.26	67.15	88.42
Before NCC-1, S-IVB				
Apogee altitude, n. mi.	159.53	6.83	146.08	183.57

TABLE III.- SUMMARY OF TRAJECTORY PARAMETERS DURING RENDEZVOUS - Continued

Parameter	Mean	Standard deviation	Smallest sample	Largest sample
Before NCC-1, S-IVB - Continued				
Perigee altitude, n. mi.	122.15	3.65	115.21	129.49
Longitude of ascending node, deg	25.59	.26	25.00	26.28
Inclination, deg	31.61	.02	31.56	31.67
Argument of perigee, deg	82.69	3.33	72.85	93.55
NCC-1, relative position				
Phasing, deg	1.25	.67	.01	2.90
Differential altitude, n. mi.	.39	1.12	-2.17	3.49
Relative range, n. mi.	78.67	42.33	2.07	181.93
NCC-1, CSM				
Longitude, deg	103.79	8.90	65.31	117.86
Latitude, deg	-29.59	1.22	-31.64	-26.85
Apogee altitude, n. mi.	198.84	6.83	179.07	214.06
Perigee altitude, n. mi.	117.97	9.07	93.86	137.27
Longitude of ascending node, deg	25.59	.26	25.01	26.27
Inclination, deg	31.61	.02	31.56	31.67
Argument of perigee, deg	18.80	9.48	-.17	42.66
Mean anomaly, deg	-89.34	9.12	-111.92	-68.21
NCC-2, CSM				
Longitude, deg	-12.68	7.06	-41.92	-.96
Latitude, deg	-6.75	4.30	-13.57	11.12
TPI shift based on ground tracking, sec	-79.30	739.77	-2370.76	2418.54
Apogee altitude, n. mi.	197.43	7.14	178.74	212.52
Perigee altitude, n. mi.	123.89	9.58	100.07	148.94

TABLE III.- SUMMARY OF TRAJECTORY PARAMETERS DURING RENDEZVOUS - Continued

Parameter	Mean	Standard deviation	Smallest sample	Largest sample
NCC-2, CSM - Continued				
Longitude of ascending node, deg	25.29	.25	24.70	25.91
Inclination, deg	31.64	.02	31.59	31.71
Argument of perigee, deg	23.07	10.27	.32	47.64
NSR, S-IVB				
Apogee altitude, n. mi.	159.16	6.33	145.13	181.05
Perigee altitude, n. mi.	123.84	3.41	116.00	129.66
Longitude of ascending node, deg	25.09	.26	24.50	25.77
Inclination, deg	31.62	.02	31.57	31.67
Argument of perigee, deg	79.93	3.06	69.69	88.84
Mean anomaly, deg	-131.13	8.81	-163.67	-115.11
NSR, relative position				
Phasing, deg	1.37	.01	1.34	1.38
Differential altitude, n. mi.	7.95	.02	-8.01	-7.89
Relative range, n. mi.	86.22	.26	85.16	86.68
NSR, CSM				
Longitude, deg	99.98	8.98	60.83	113.95
Latitude, deg	-24.47	2.69	-31.65	-19.24
Apogee altitude, n. mi.	151.59	6.20	139.41	176.12
Perigee altitude, n. mi.	114.92	3.29	107.85	121.98
Longitude of ascending node, deg	25.10	.26	24.51	25.78
Inclination, deg	31.62	.02	31.57	31.67
Argument of perigee, deg	80.13	3.07	69.71	88.99
Mean anomaly, deg	-132.71	8.77	-165.01	-116.66

TABLE III.- SUMMARY OF TRAJECTORY PARAMETERS DURING RENDEZVOUS - Continued

Parameter	Mean	Standard deviation	Smallest sample	Largest sample
TPI, relative position				
Phasing, deg	.25	.004	.24	.26
Differential altitude, n. mi.	-8.05	.13	-8.40	-7.72
Relative range, n. mi.	17.40	.28	16.69	18.16
TPI shift based on relative tracking, sec	-4.15	84.66	-202.35	259.29
TPI, CSM				
Longitude, deg	51.29	13.32	-4.09	81.15
Latitude, deg	-30.12	1.59	-31.65	-23.52
Apogee altitude, n. mi.	150.97	6.58	138.28	173.42
Perigee altitude, n. mi.	121.95	3.57	114.97	131.38
Longitude of ascending node, deg	24.69	.27	24.10	25.39
Inclination, deg	31.61	.02	31.56	31.68
Argument of perigee, deg	83.73	4.64	68.88	91.36
MCC1, relative position				
Phasing, deg	.06	.003	.05	.07
Differential altitude, n. mi.	-5.15	.12	-5.45	-4.76
Relative range, n. mi.	6.51	.14	6.08	6.84
MCC1, CSM				
Apogee altitude, n. mi.	154.39	6.17	142.80	179.71
Perigee altitude, n. mi.	123.27	3.56	113.38	130.21
Longitude ascending node, deg	24.61	.26	24.02	25.27
Inclination, deg	31.63	.02	31.59	31.69
Argument of perigee, deg	71.82	5.09	57.15	82.47
Mean anomaly, deg	-93.35	15.95	-154.32	-59.77

TABLE III.- SUMMARY OF TRAJECTORY PARAMETERS DURING RENDEZVOUS - Concluded

Parameter	Mean	Standard deviation	Smallest sample	Largest sample
MCC2, relative position				
Phasing, deg	.01	.003	0.0	.02
Differential altitude, n. mi.	-3.11	.07	-3.30	-2.87
Relative range, n. mi.	3.23	.09	2.90	3.49
MCC2, CSM				
Apogee altitude, n. mi.	157.22	5.55	145.50	178.12
Perigee altitude, n. mi.	121.19	4.24	111.76	131.87
Longitude of ascending node, deg	24.60	.25	24.02	25.24
Inclination, deg	31.64	.02	31.60	31.70
Argument of perigee, deg	72.46	3.38	60.81	82.71
Mean anomaly, deg	-65.82	12.77	-123.31	-39.69
TPF, CSM				
DCA shift, sec	-2.53	38.94	-107.90	128.33
Apogee altitude, n. mi.	164.09	7.72	146.56	194.56
Perigee altitude, n. mi.	117.31	3.76	108.94	127.30
Longitude of ascending node, deg	24.55	.27	23.97	25.22
Inclination, deg	31.61	.03	31.56	31.70
Argument of perigee, deg	84.61	4.03	71.67	96.69
Mean anomaly, deg	-21.20	10.39	-58.79	1.28

TABLE IV.- SPS-1 INDIVIDUAL MANEUVER ANALYSIS^a

Parameter	Nominal	Without point error				With pointing error			
		Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum
V, fps	209.08	209.08	---	208.87	209.32	209.07	---	208.76	209.44
V _u , fps	-203.00	-203.01	---	-202.56	-203.49	-202.90	.48	-202.20	-204.48
V _v , fps	50.08	50.10	---	49.67	50.67	50.29	1.90	44.39	53.80
V _w , fps	1.34	1.34	---	.90	1.67	1.66	2.10	-3.19	6.22
V _g , fps	---	---	---	---	---	2.70	1.40	.65	6.31
V _{gx} , fps	---	---	---	---	---	2.00	-3.60	6.21	
V _{gy} , fps	---	---	---	---	---	.25	2.20	-5.30	4.90
V _{gz} , fps	---	---	---	---	---	---	---	-.64	1.90
ΔT _b , sec	10.13	10.13	.04	10.04	10.19	10.13	.04	10.04	10.19
ΔW _t , lb	648.18	647.83	2.35	642.16	652.17	647.83	2.35	642.16	652.17
H _a , n. mi.	196.66	196.68	---	196.48	196.85	196.60	0.51	195.20	197.60
H _p , n. mi.	119.84	119.85	---	119.66	119.98	119.80	0.62	117.90	120.90
ω, deg	22.38	22.36	.09	22.14	22.57	22.22	0.86	20.01	24.80
θ, deg	25.59	25.59	---	25.58	25.59	25.59	---	25.59	25.59
i, deg	31.61	31.61	---	31.61	31.61	31.61	---	31.61	31.61
ϕ, deg	-29.02	-29.02	---	-29.02	-29.02	-29.02	---	-29.02	-29.02
λ, deg	108.58	108.58	---	108.58	108.58	108.58	---	108.58	108.58

^aBlank spaces in the 3σ dispersions mean

V, V_u, V_v, V_w < 1 fps h_a, h_p < 0.5 n. mi.
V_g, V_{gx}, V_{gy}, V_{gz} < 1 fps ω, θ, i, ϕ, λ < 0.1°

TABLE V.- SPS-2 INDIVIDUAL MANEUVER ANALYSIS^a

Parameter	Nominal	Without pointing error				With pointing error			
		Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum
v , fps	185.98	185.95	---	185.52	186.36	185.84	---	184.90	186.20
v_u , fps	165.85	165.83	---	165.15	166.36	165.57	1.26	161.2	167.5
v_v , fps	-84.16	-84.14	---	-83.60	-84.51	-84.31	2.32	-81.10	-91.00
v_w , fps	-36	-42	---	-1.13	.29	-.70	2.80	-6.60	6.40
v_g , fps	---	---	---	---	---	3.45	1.80	.50	8.20
v_{gx} , fps	---	---	---	---	---	---	2.74	-4.70	8.02
v_{gy} , fps	---	---	---	---	---	---	2.80	-6.20	6.70
v_{gz} , fps	---	---	---	---	---	-.10	---	-1.30	.10
ΔT_b , sec	8.80	8.80	.04	8.73	8.87	8.80	.04	8.73	8.87
ΔW_t , lb	563.02	562.87	2.11	556.96	567.39	562.87	2.11	556.96	567.39
H_a , n. mi.	152.05	152.06	---	151.96	152.14	152.10	---	151.93	152.30
H_p , n. mi.	116.10	116.11	---	115.86	116.43	116.01	1.20	112.40	118.10
ω , deg	82.37	82.35	.18	81.99	82.77	82.33	1.16	80.00	85.20
Ω , deg	25.10	25.10	---	25.09	25.10	25.10	---	25.08	25.11
i, deg	31.62	31.62	---	31.62	31.62	31.62	---	31.62	31.62
ϕ , deg	-23.11	-23.11	---	-23.11	-23.11	-23.11	---	-23.11	-23.11
λ , deg	104.76	104.77	---	104.77	104.76	104.76	---	104.76	104.77

^aBlank spaces in the 3σ dispersions mean

$v, v_u, v_v, v_w < 1$ fps $h_a, h_p < 0.5$ n. mi.
 $v_g, v_{gx}, v_{gy}, v_{gz} < 1$ fps $\omega, \Omega, i, \phi, \lambda < 0.1^\circ$

TABLE VI.- SPS-3 INDIVIDUAL MANEUVER ANALYSIS^a

[Without pointing error]					
Parameter	Nominal	Mean	Standard deviation	Minimum	Maximum
V, fps	261.39	261.39	1.20	258.90	264.72
V _u , fps	30.67	30.69	0.63	29.43	32.14
V _v , fps	-57.98	-57.98	0.56	-56.61	-59.00
V _w , fps	253.02	253.02	1.17	251.13	255.04
V _g , fps	0.00	---	---	---	---
V _{gx} , fps	0.00	---	---	---	---
V _{gy} , fps	0.00	---	---	---	---
V _{gz} , fps	0.00	---	---	---	---
ΔT _b , sec	12.17	12.16	.07	11.97	12.36
ΔW _t , lb	778.45	777.96	4.46	766.14	787.70
H _a , n. mi.	150.28	150.28	---	150.02	150.50
H _p , n. mi.	96.07	96.04	0.32	95.30	96.69
ω, deg	94.09	94.07	0.34	93.43	94.80
Ω, deg	4.80	4.80	---	4.79	4.81
i, deg	31.18	31.18	---	31.17	31.19
ϕ, deg	-19.37	-19.37	---	-19.37	-19.38
λ, deg	-254.41	-254.42	---	-254.40	-254.43

^aBlank spaces in the 3σ dispersions mean

V, V_u, V_v, V_w < 1 fps

h_a, h_p < 0.5 n. mi.

V_g, V_{gx}, V_{gy}, V_{gz} < 1 fps

ω, Ω, i, ϕ, λ < 0.1°

TABLE VII.- SPS-4 INDIVIDUAL MANEUVER ANALYSIS^a

[Without pointing error]					
Parameter	Nominal	Mean	Standard deviation	Minimum	Maximum
V, fps	13.14	13.26	.68	11.59	14.75
V _u , fps	-.33	-.34	---	-.24	-.44
V _v , fps	13.14	13.26	.68	11.58	14.74
V _w , fps	.00	.01	---	-.11	.07
V _g , fps	1.80	1.75	.68	.21	3.54
V _{gx} , fps	1.80	1.75	.68	.21	3.54
V _{gy} , fps	0.00	---	---	---	---
V _{gz} , fps	0.00	---	---	---	---
ΔT _b , sec	.56	.56	0.00	.56	.57
ΔW _t , lb	35.83	36.49	2.77	29.52	42.27
H _a , n. mi.	158.30	158.37	.38	157.41	159.17
H _p , n. mi.	88.75	88.75	---	88.72	88.78
ω, deg	105.23	105.23	.05	105.13	105.34
Ω, deg	355.53	255.53	---	255.53	255.54
i, deg	31.16	31.16	---	31.16	31.16
φ, deg	28.20	28.20	---	28.20	28.20
λ, deg	279.86	279.86	---	279.86	279.86

^aBlank spaces in the 3σ dispersions mean

V, V_u, V_v, V_w < 1 fps h_a, h_p < 0.5 n. mi.
 V_g, V_{gx}, V_{gy}, V_{gz} < 1 fps ω, Ω, i, φ, λ < 0.1°

TABLE VIII.- SPS-5 INDIVIDUAL MANEUVER ANALYSIS^a

[Without pointing error]					
Parameter	Nominal	Mean	Standard deviation	Minimum	Maximum
V, fps	1280.20	1280.27	.57	1279.17	1281.59
V _u , fps	411.06	411.24	.67	409.54	412.74
V _v , fps	136.05	136.10	.52	134.84	137.41
V _w , fps	1204.75	1204.80	.54	1203.84	1206.06
V _g , fps	---	---	---	---	---
V _{gx} , fps	---	---	---	---	---
V _{gy} , fps	---	---	---	---	---
V _{gz} , fps	---	---	---	---	---
ΔT _b , sec	56.28	56.28	.21	55.83	56.64
ΔW _t , lb	3600.79	3598.62	12.48	3567.47	3625.24
H _a , n. mi.	233.71	233.75	.26	232.88	234.43
H _p , n. mi.	86.76	86.75	---	86.61	86.86
ω, deg	47.18	47.18	.08	46.93	47.35
Ω, deg	346.64	346.65	.00	346.64	346.65
i, deg	31.66	31.66	.00	31.66	31.67
φ, deg	31.00	31.00	.00	31.00	31.01
λ, deg	-75.60	-75.60	---	-75.63	-75.57

^aBlank spaces in the 3σ dispersions meanV, V_u, V_v, V_w < 1 fpsh_a, h_p < 0.5 n. mi.V_g, V_{gx}, V_{gy}, V_{gz} < 1 fps

ω, Ω, i, φ, λ < 0.1°

TABLE IX.- SPS-6 INDIVIDUAL MANEUVER ANALYSIS^a

Parameter	Nominal	Mean	Standard deviation	[Without pointing error]	
				Minimum	Maximum
V, fps	14.84	14.97	.76	13.08	16.64
V _u , fps	-.38	-.38	---	-.27	-.50
V _v , fps	14.83	14.96	.76	13.08	16.64
V _w , fps	0.00	0.01	---	-.12	.15
V _g , fps	2.01	2.33	1.55	.15	8.94
V _{gx} , fps	2.01	2.33	1.55	.15	8.94
V _{gy} , fps	.00	.00	---	.00	.00
V _{gz} , fps	.00	.00	---	.00	.00
ΔT _b , sec	.56	.56	.00	.56	.56
ΔW _t , lb	35.83	36.30	2.75	29.52	42.27
H _a , n. mi.	238.45	238.52	.45	237.28	239.42
H _p , n. mi.	85.17	85.17	---	85.13	85.22
ω, deg	68.35	68.35	---	68.32	68.39
Ω, deg	332.55	332.55	---	332.55	332.56
i, deg	31.67	31.67	---	31.67	31.67
ϕ, deg	28.77	28.77	---	28.77	28.77
λ, deg	-83.95	-83.95	---	-83.94	-83.86

^aBlank spaces in the 3σ dispersions meanV, V_u, V_v, V_w < 1 fpsh_a, h_p < 0.5 n. mi.V_g, V_{gx}, V_{gy}, V_{gz} < 1 fps

ω, Ω, i, ϕ, λ < 0.1°

TABLE X.- SPS-7 INDIVIDUAL MANEUVER ANALYSIS^a

[Without pointing error]					
Parameter	Nominal	Mean	Standard deviation	Minimum	Maximum
V, fps	495.16	495.16	2.31	490.39	501.56
V _u , fps	-352.10	-352.02	1.21	-348.61	-356.72
V _v , fps	-45.14	-45.22	1.22	-42.74	-48.36
V _w , fps	345.21	345.28	1.94	340.76	349.66
V _g , fps	---	---	---	---	---
V _{gx} , fps	---	---	---	---	---
V _{gy} , fps	---	---	---	---	---
V _{gz} , fps	---	---	---	---	---
ΔT _b , sec	19.67	19.66	.11	19.36	19.97
ΔW _t , lb	1258.49	1257.60	6.90	1237.90	1272.69
H _a , n. mi.	215.39	215.35	.69	213.52	216.74
H _p , n. mi.	85.98	85.98	---	85.82	86.15
ω, deg	121.14	121.14	.23	120.73	121.56
Ω, deg	326.16	326.16	---	326.15	326.18
i, deg	31.51	31.51	---	31.50	31.51
ϕ, deg	30.75	30.75	---	30.75	30.76
λ, deg	-76.31	-76.31	---	-76.29	-76.34

^aBlank spaces in the 3σ dispersions meanV, V_u, V_v, V_w < 1 fpsh_a, h_p < 0.5 n. mi.V_g, V_{gx}, V_{gy}, V_{gz} < 1 fps

ω, Ω, i, ϕ, λ < 0.1°

TABLE XI.- SPS-8 INDIVIDUAL MANEUVER ANALYSIS^a

Parameter	Nominal	Without pointing error						With pointing error		
		Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum	
V , fps	260.12	260.11	---	259.75	260.39	260.13	---	259.83	260.51	
V_u , fps	-189.85	-189.88	---	-190.56	-189.32	-190.07	2.35	-185.77	-197.05	
V_v , fps	-177.82	-177.93	---	-178.21	-177.23	-177.52	2.57	-169.75	-182.02	
V_w , fps	.00	-.01	---	-.48	.47	-.57	3.68	-.08	8.84	
V_g , fps	---	---	---	---	---	4.52	2.35	.57	10.38	
V_{gx} , fps	---	---	---	---	---	.10	---	-.12	.39	
V_{gy} , fps	---	---	---	---	---	-.46	3.68	-.810	8.78	
V_{gz} , fps	---	---	---	---	---	-.07	3.49	-10.38	6.28	
ΔT_b , sec	9.81	9.80	.04	9.72	9.87	9.81	.04	9.72	9.87	
HW_t , lb	627.38	626.91	2.60	619.91	632.07	627.38	2.60	619.91	632.07	
H_a , n. mi.	203.07	203.08	---	202.96	203.20	203.14	.70	201.87	205.27	
H_p , n. mi.	3.24	3.26	---	3.09	3.48	3.32	.78	1.98	5.65	
ω , deg	159.29	159.28	.03	159.20	159.36	159.24	.45	157.85	160.06	
Ω , deg	318.96	318.96	---	318.96	318.97	318.96	---	318.94	318.99	
i, deg	31.53	31.53	---	31.53	31.53	31.53	---	31.51	31.54	
ϕ , deg	20.16	20.16	---	20.16	20.16	20.16	---	20.15	20.16	
λ , deg	-147.34	-147.34	---	-147.35	-147.34	-147.34	---	-147.34	-147.35	

^aBlank spaces in the 3σ dispersions mean $V, V_u, V_v, V_w < 1$ fps
 $h_a, h_p < 0.5$ n. mi. $V_g, V_{gx}, V_{gy}, V_{gz} < 1$ fps
 $\omega, \Omega, i, \phi, \lambda < 0.1^\circ$

TABLE XII.- SPS PROPELLANT FOR APOLLO 7

Maneuver	Nominal, lb	Mean, lb	Standard Deviation, lb	3-Sigma Deviation, lb
SPS-1	646.39	647.83	2.35	7.05
SPS-2	561.50	562.87	2.11	6.33
SPS-3	776.01	777.96	4.46	^a 13.38
SPS-4	31.66	36.49	2.77	8.31
SPS-5	3587.66	3598.62	12.48	^b 37.44
SPS-6	31.41	36.30	2.75	8.25
SPS-7	1253.39	1257.60	6.90	20.70
SPS-8	624.70	626.91	2.60	7.80
TOTALS	7512.72	7544.58	36.42	109.26

^aIf the SPS-3 maneuver is retargeted to cause the sum of the burn time for the first 3 SPS maneuvers to be 31.1 seconds, then the dispersions for the first two maneuvers are removed and the total 3-sigma deviation becomes 13.38 pounds less.

^bSince the SPS-5 maneuver is cut off manually, 65 pounds should be added to the 3-sigma deviation for the maneuver.

TABLE XIII.- UNIT G&N SYSTEM ERROR ANALYSIS SUMMARY FOR THE SPS-1 AND SPS-2 MANEUVERS

Source	Errors	SPS-1				SPS-2			
		Magnitude	$\Delta(\Delta V)$, fps	$\dot{\Delta U}$, fps	$\dot{\Delta V}$, fps	$\dot{\Delta W}$, fps	$\Delta(\Delta V)$, fps	$\dot{\Delta U}$, fps	$\dot{\Delta V}$, fps
Nominal		209.09	-203.00	50.08	1.34	185.98	165.85	-84.16	-36
X bias	.01 ft/sec ²	-.04	-.02	-.29	.00	.02	-.18	-.37	.00
	.10 ft/sec ²	-.39	-.29	-.88	.00	.14	-.80	-.75	.02
	.40 ft/sec ²	-1.36	-1.11	-11.53	.00	.56	-7.70	-14.76	.08
Y bias	.01 ft/sec ²	.00	.00	.00	.29	.00	.00	.00	.41
	.10 ft/sec ²	.03	.00	.00	2.90	.00	-.02	.04	.16
	.40 ft/sec ²	.32	.07	-.02	11.61	.03	-.58	.38	16.64
Z bias	.01 ft/sec ²	-.25	.26	-.02	.00	.24	.23	-.09	.00
	.10 ft/sec ²	-2.84	2.52	-.15	.00	2.40	2.25	-.87	.00
	.40 ft/sec ²	-9.42	9.93	-.54	.01	9.66	8.91	-.380	-.01
X scale factor	1.0001 n.d.	.00	.00	-.01	.00	.00	.00	.00	.00
	1.0010 n.d.	-.01	.00	-.04	.00	.00	.01	.02	.00
	1.0050 n.d.	-.03	-.01	-.19	.00	.00	.04	.08	.00
Y scale factor	1.0001 n.d.	.00	.00	.00	.00	.00	.00	.00	.00
	1.0010 n.d.	.00	.00	.00	.00	.00	.00	.00	.00
	1.0050 n.d.	.00	.00	.00	-.01	.00	.00	.00	.00
Z scale factor	1.0001 n.d.	-.02	.03	.00	.00	.00	-.02	.01	.00
	1.0010 n.d.	-.21	.21	-.01	.00	-.18	-.17	.07	.00
	1.0050 n.d.	-1.02	1.04	-.06	.00	-.92	-.86	.34	.00
X gyro drift	2 meru	.00	.00	.00	.06	.00	.00	.00	-.05
	20 meru	.00	.00	.00	.55	.00	.00	.00	.49
	100 meru	.00	1.98	-.16	27.19	.00	-1.59	.58	-24.57
Y gyro drift	2 meru	.00	.01	.05	.00	.00	-.02	-.04	.00
	20 meru	.00	.14	.53	.00	.00	-.22	-.44	.00
	100 meru	.00	8.37	26.31	.00	.00	-12.59	-21.21	.11
Z gyro drift	2 meru	.00	.00	.00	-.01	.00	.00	.00	.00
	20 meru	.00	.00	.00	-.08	.00	.00	.00	.03
	100 meru	.00	.00	-.10	-3.29	.00	.00	-.06	1.35

TABLE XIII.- UNIT G&N SYSTEM ERROR ANALYSIS SUMMARY FOR THE SPS-1 AND SPS-2 MANEUVERS - Concluded

Source	Errors	Magnitude	SPS-1			SPS-2		
			$\Delta(\Delta V)$, fps	$\Delta\dot{U}$, fps	$\Delta\dot{V}$, fps	$\Delta\dot{W}$, fps	$\Delta(\Delta V)$, fps	$\Delta\dot{U}$, fps
Accelerometer misalignment								
XY	1 min of arc	.00	.00	.00	.00	.00	.00	.00
	5 min of arc	.00	.00	.00	.00	.00	.00	.00
	15 min of arc	.00	.01	.01	.00	.00	.00	.00
XZ	1 min of arc	-.01	.00	-.07	.00	.00	-.04	.09
	5 min of arc	-.05	-.03	-.34	.00	-.01	.20	.43
	15 min of arc	-.15	-.10	-.130	.00	-.04	.60	1.28
YX	1 min of arc	.00	.00	.01	.00	.00	.00	.00
	5 min of arc	.00	.00	.06	.00	.00	.00	.00
	15 min of arc	.00	.00	.17	.00	.00	.00	-.08
YZ	1 min of arc	.00	.00	.07	.00	.00	.00	-.11
	5 min of arc	.00	.00	.35	.00	.00	.00	-.47
	15 min of arc	.00	.00	1.04	.01	-.01	.00	-1.42
ZX	1 min of arc	-.01	.01	.00	.00	.00	.00	.00
	5 min of arc	-.05	.05	.00	.00	-.01	-.01	.00
	15 min of arc	-.15	.15	-.01	.00	-.04	-.04	.02
ZY	1 min of arc	.00	.00	.00	.00	.00	.00	.00
	5 min of arc	.00	.00	.00	.00	.01	.00	.00
	15 min of arc	.00	.00	.00	.00	.01	.00	.00

TABLE XIV.- UNIT G&N ERROR ANALYSIS SUMMARY FOR THE SPS-5 AND SPS-8 MANEUVERS

Errors		SPS-5				SPS-8			
Source	Magnitude	$\Delta(\Delta V)$, fps	$\Delta\dot{U}$, fps	$\Delta\dot{V}$, fps	$\Delta\dot{W}$, fps	$\Delta(\Delta V)$, fps	$\Delta\dot{U}$, fps	$\Delta\dot{V}$, fps	$\Delta\dot{W}$, fps
Nominal		1280.20	411.06	136.05	1204.75	260.12	-189.85	-177.82	.00
X bias	.01 ft/sec ²	-.77	-.21	-.08	-.74	.25	-.19	-.16	.00
	.10 ft/sec ²	-7.11	-2.10	-.84	-7.37	2.50	-.189	-.163	-.04
	.40 ft/sec ²	-30.45	-8.29	-3.33	-29.15	10.10	-.764	-.61	-.16
Y bias	.01 ft/sec ²	.00	.02	-.76	.09	.00	.00	.00	.29
	.10 ft/sec ²	.05	.24	-7.68	.81	.05	-.02	-.02	2.89
	.40 ft/sec ²	.47	.99	-30.74	3.24	.34	-.07	-.05	11.54
Z bias	.01 ft/sec ²	.04	.74	.01	-.21	.01	.19	-.21	.00
	.10 ft/sec ²	.42	7.44	.02	-2.11	.10	1.91	-2.16	.00
	.40 ft/sec ²	1.98	29.78	.07	-8.46	.54	7.68	-.865	.00
X scale factor	1.0001 n.d.	-.13	-.04	-.01	-.12	-.03	.02	.02	.00
	1.0010 n.d.	-1.28	-.35	-.14	-1.22	-.26	.20	.17	.01
	1.0050 n.d.	-6.37	-1.64	-.69	-6.09	-.29	.98	.85	.02
Y scale factor	1.0001 n.d.	.00	.00	.00	.00	.00	.00	.00	.00
	1.0010 n.d.	.00	.00	.01	.00	.00	.00	.00	.00
	1.0050 n.d.	.00	.00	.02	.00	.00	.00	.00	-.02
Z scale factor	1.0001 n.d.	.00	-.01	.00	.01	.00	.00	.00	.00
	1.0010 n.d.	.00	-.07	.00	.02	.00	-.01	.01	.00
	1.0050 n.d.	-.02	-.32	.00	.09	.00	-.04	.04	.00
X gyro drift	2 meru	.00	.00	.02	.00	.00	.00	.00	.00
	20 meru	.00	.00	.18	-.02	.00	.01	-.01	-.02
	100 meru	.00	-.34	8.84	-.91	.00	.27	-.28	-1.20
Y gyro drift	2 meru	.00	.32	.00	-.11	.00	-.05	.05	.00
	20 meru	.00	3.25	-.01	-1.11	.00	-.47	.50	.00
	100 meru	.00	158.45	-.87	-66.09	.00	-21.77	26.56	.01
Z gyro drift	2 meru	.00	-.01	.33	-.03	.00	.00	.00	.07
	20 meru	.00	-.10	3.21	-.33	.00	.00	.00	.67
	100 meru	.00	-7.83	159.81	-26.29	.00	1.62	1.43	33.45

TABLE XIV.- UNIT G&N ERROR ANALYSIS SUMMARY FOR THE SPS-5 AND SPS-8 MANEUVERS - Concluded

Source	Magnitude	SPS-5				SPS-8			
		$\Delta(\Delta V)$, fps	$\Delta\dot{U}$, fps	$\Delta\dot{V}$, fps	$\Delta\dot{W}$, fps	$\Delta(\Delta V)$, fps	$\Delta\dot{U}$, fps	$\Delta\dot{V}$, fps	$\Delta\dot{W}$, fps
Accelerometer misalignment									
XY	1 min of arc	.00	.00	.01	.00	.00	.00	.00	.00
	5 min of arc	.01	.00	.01	.01	.00	.00	.00	.00
	15 min of arc	.03	.01	.03	-.01	.01	.01	.01	.00
XZ	1 min of arc	.02	.00	.01	.02	.00	.00	.00	.00
	5 min of arc	.10	.02	.01	.10	-.01	.01	.01	.00
	15 min of arc	.30	.08	.03	.29	-.04	.03	.03	.00
YX	1 min of arc	.00	.01	-.37	.04	.00	.00	.00	-.09
	5 min of arc	.01	.06	-.1.84	.20	.00	.00	.00	-.44
	15 min of arc	.03	.18	-.5.54	.59	-.01	.01	.01	-.1.31
YZ	1 min of arc	.00	.00	.02	.00	.00	.00	.00	.00
	5 min of arc	.00	-.01	.10	-.01	.00	.00	.00	-.01
	15 min of arc	.00	-.01	.29	-.03	.00	.00	.00	-.04
ZX	1 min of arc	.02	.36	.00	-.10	.00	-.06	.07	.00
	5 min of arc	.10	1.79	.01	-.50	-.01	-.29	.33	.00
	15 min of arc	.30	5.37	.02	-1.52	-.03	-.87	.99	.00
ZY	1 min of arc	.00	.00	.00	.00	.00	.00	.00	.00
	5 min of arc	.00	-.01	.00	.01	.00	-.01	.01	.00
	15 min of arc	.00	-.02	.00	.01	.00	-.01	.01	.00

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